

PATENT SPECIFICATION

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(54) SINTERED Fe-Ti CARBIDE PARTS

(71) We, JOHNSON PRODUCTS INC., a Corporation organised and existing under the Laws of the State of Michigan, United States of America, of 1185 East Keating, Muskegon, Michigan, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to machinable metal parts such as engine components having high wearability and to methods of forming such parts.

Hardened iron parts such as iron castings have been the mainstay for years in a host of apparatus and machinery environments where excessive wear and potential failure occurs not infrequently. For example, it has become apparent that excessive wear and potential failure occurs not infrequently for engine components, especially tappet surfaces and cooperative cam lobes of cam shafts and rocker arms. Evaluations show frequent loss of hardness in such items to a detrimental extent. Severe loss of hardness is believed to be caused by excessive superficial heat generated by direct metal-to-metal contact of the parts. Such contact is generally caused by lubrication breakdowns occurring in a variety of different environments such as present-day high compression engines which frequently have long periods between oil changes.

Extensive experimental testing has been conducted under the direction of the inventor producing significant advances for engine components such as tappets, cam shafts, cam lobes, rotary (e.g. Wankel) engine seals, and rocker arms as evidenced by United States Letters Patent 3,370,941, 3,472,651 and 3,627,515, which describe inventions utilising iron casting.

Recently, as a result of continued investigation into ways and means for producing a longer lasting higher wearing metal part at reduced economical expenditures, the production of metal parts including engine components by briquetting and sintering powdered metal has shown promise the economical advantages in utilising powdered metal parts is significant. However, adequate hardness and wearability have been a constant problem in utilising this method. Wearability of the order of 0.002 inch after 1,000 hours of operation is acceptable in the present state of the engine component art. However, adequate wearability has been unobtainable to date in a powdered metal part. Thus, there is a need in this art for a metal part produced by heat sintering powdered metals, the resultant product of which provides acceptable wearability.

According to one aspect of the present invention, a metal part comprises titanium carbide particles with a hardness of 70 or more on the Rockwell C scale and formed by the steps of: preparing a mixture of powdered material having 0.25 to 60 percent by weight ferro titanium and 0.1 to 10 percent by weight carbon, the remainder of said powdered material being substantially iron based powder; compacting said mixture; and heat sintering said mixture above the melting temperature of the ferro titanium powder and below the melting point of the iron based powder whereby the ferro titanium melts and dissolves available carbon in the surrounding matrix to form titanium carbide particles.

According to another aspect of the present invention, a method of forming a metal part comprises the steps of: preparing a mixture of powdered material having 0.25 to 60 percent by weight ferro titanium and 0.1 to 10 percent by weight carbon, the remainder of said powdered material being

substantially iron based powder; compacting said mixture and heat sintering said mixture above the melting temperature of the ferro titanium powder and below the melting point of the iron based powder whereby the ferro titanium melts and dissolves available carbon in the surrounding matrix to form titanium carbide particles.

A commercial grade ferro titanium containing 70% titanium works quite well with the particle size varying from 40 mesh and down to 325 mesh or even smaller. As used herein the term "mesh size" has the meaning given at page 955 of "Chemical Engineers Handbook" (editor-in-chief: John N. Perry), 3rd Edition (1950), published by McGraw-Hill Book Company, Inc. that is to say the term "mesh size" means the number of openings per linear inch. Where desired, the mixture of iron powder, ferro titanium and carbon can contain other alloying elements added to the basic mixture. The addition of these other alloying elements however is not essential.

The resultant parts which may be engine components such as those listed above have been found to have very good wearability and may possibly be as much as 40-50 times better than those made of the materials currently being used in industry. The process is both simple and extremely economical.

Generally speaking, the present invention provides a heat sintered powdered mixture which coacts synergistically to provide a metal part having very good physical properties at low cost and particularly adapted for use as engine components in high compression engines.

The significant steps utilised are to mix controlled amounts of carbon and ferro titanium powders with the powdered balance, e.g. iron powder. The controlled amounts of the mixture by weight are between 0.1% and 10% carbon, preferably in the range of 0.5% to 1.5%, and between 0.25% and 60% ferro titanium, preferably in the range of 1.0% to 10%. The remainder is substantially iron although the presence of other metals is permissible, the significance of which will be described hereinafter. The mixture is pressure compacted (briquetted) into a desired shape and heat sintered, preferably for a period of approximately 1 hour, to at least approximately 2000°F in order to melt the ferro titanium. Preferably the sintering temperature is at least 2100°F.

The ferro titanium powder may be a commercially available grade containing about 70% titanium powder with a particle size varying from 40 mesh and down to 325 mesh or less. The ferro titanium powder used melts between approximately 2000°F and 2012°F and a significant aspect of the

process is that in the sintering operation, the ferro titanium actually melts and dissolves some or all of the available carbon in the surrounding matrix to form titanium carbide particles. These titanium carbide particles are extremely hard particles ranging upwardly from 70 on the Rockwell C scale. Generally the range has been found to be between 70 and 90 on the Rockwell C scale using a micro hardness tester. The resultant formation of these titanium carbide particles forms a very hard wear-resistant metal. Extensive testing has indicated improved wearability of the order of 40-50 times better than materials currently used in the industry. Based on present test results a 1,000 hour test will yield less than 0.002 inch wear.

The size and quantity of titanium carbides vary with the percentage and size of the ferro titanium addition. While the mesh size of the iron powder is not of any particular significance in this regard, standard commercial sizes of the order of 40 mesh and down have proved to work extremely well. Higher mesh sizes however will work.

Turning to the basic mixture itself, a number of tests have been conducted utilising various amounts by weight of the iron, carbon and ferro titanium powders. These tests are set forth in detail below. Greater ranges than presently tested however should work equally well.

One of the more significant aspects of the invention is the synergistic result of mixing, briquetting and heat sintering the ferro titanium powder with controlled amounts of carbon. As little as 0.25% by weight ferro titanium powder is believed to be adequate. Due to present costs of commercially available ferro titanium powder, a practical limit of 60% by weight ferro titanium powder is imposed due to the present competitive aspects of this art. Regarding the carbon content, a particular range by weight of between 0.1% and 10% is imposed since lower amounts will not produce enough titanium carbide particles and higher amounts present problems in briquetting and other related strength factors of the resultant metal part.

EXAMPLE I

As a specific example, a powdered mixture of the following percentages by weight was thoroughly mixed by standard procedures in this art: 5% ferro titanium; 0.9% carbon; 2.0% copper; and 92.1% iron. The mesh size of the ferro titanium powder was from 40 down to 325 and the iron powder was from 80 mesh and down. A commercially available iron powder was used which included the carbon and copper. The mixture was compressed by a conventional press into a cylindrical briquette

having a diameter of 1.0 inch and a length of $2\frac{1}{8}$ inches. The press utilised developed approximately 36 tons per square inch. The size compared closely to that of a standard tappet body for use in an internal combustion engine.

The briquette was heat sintered for 6.0 hours. It was gradually heated from approximately 80°F to 2100°F in two hours and maintained at approximately 2100°F for a period of one hour. It was then cooled gradually down to 825°F over a period of three hours. After complete cooling to room temperature, the resultant metal part was machined for proper tolerance and tested for wearability. Present test indications predict cam face wear of less than 0.002 inch after 1,000 test hours which is well within acceptable limits.

The presence of copper in the foregoing example was arbitrary in that the particular commercial grade iron powder included it.

The presence of certain other alloying elements does not eliminate the advantageous properties of the material as illustrated by the presence of molybdenum in other examples set forth. Minor impurities such as phosphorus or sulphur also do not have large effects on the method or resultant part.

In order to provide some examples showing the use of controlled amounts of alloying elements, the following samples were made up in accordance with the invention and subsequently tested and subjected to micro examination. The percentages listed are by weight of the powdered mixture which was subsequently briquetted in a 36 ton press and heat sintered. The weight given is in grams, the volume in millilitres and density in grams per cubic centimetre. The hardness listed indicates overall hardness of the sample on the Rockwell B scale after sintering.

Sample	%C	%Cu	%Mo	%FeTi	Wt.	Vol.	Den.	Hardness
1	0.9	2.0	—	5.0	23.11	3.4	6.80	82.0
2	1.7	—	0.6	10.0	22.80	3.3	6.90	71.0
3	0.9	2.0	—	5.0	24.49	3.6	6.79	80.0
4	1.7	—	0.6	5.0	23.28	3.4	6.81	57.0
5	1.7	1.5	0.6	7.5	23.79	3.6	6.60	81.0

The ferro titanium addition utilised in samples 1 and 2 had a mesh particle size of 40 down to 325 while that utilised in samples 3 to 5 had a mesh size of 325 and smaller. The ferro titanium powder utilised is available from Chemalloy Company Inc., Bryn Marr, Pennsylvania, 19010, United States of America, ordered as commercial quality ferro titanium powder specifying percent grade and mesh size. The 0.9% carbon materials were made from Hoeganaes Anchorsteel 1000 base iron powder available from Hoeganaes Corporation, River-ton, New Jersey, U.S.A., while the 1.7% carbon materials were made from Quebec Atomet-28 base iron powder available from Quebec Metal Powders Ltd. having an outlet in Southfield, Michigan, U.S.A. The heat sintering cycle for samples 1 to 5 was identical to that described previously with regard to example 1.

Samples 1 to 5 were tested in an Alpha Model LFW-1 Friction and Wear Testing Machine available from the Dow Corning Company. Various specimens of each sample were tested against a 4620 C ring having a minimum hardness of 58 on the Rockwell C scale and a hardenable iron ring having a minimum hardness of 55.0 on the Rockwell C scale. Each test lasted approximately 23.3 hours subjecting the sample to approximately 275,000 cycles, the Model

LFW-1 operating at 197 cycles per minute. In addition to the testing of samples 1 to 5, a test was also conducted using a conventional sample of hardenable iron presently being used, for comparative purposes. The hardenable iron sample used had a size comparable to that of samples 1 to 5 and a minimum hardness of 55.0 on the Rockwell C scale thereby exceeding the overall hardness of the test samples. The results are tabulated in the following table. Samples 1 to 5 are the five previously referred to samples while sample 6 is the comparative hardenable iron test sample. The wear figure is in volume loss in cubic inches times ten to the negative sixth (10^{-6}) power.

Sample	Wearability 4620 C Ring	Wearability Hard. Iron Ring
1	5.2 & 6.2	28.4
2	5.7 & 9.0	7.0 & 8.1
3	6.7 & 5.9	8.0
4	1.2 & 2.8	3.9
5	2.9, 7.0 & 1.8	5.8 & 5.3
6	43.6	368.7 & 284.0

The foregoing table indicates a totally unexpected improved wearability over what is in use today from a minimum factor of about 5 to 1 to as high as 94 to 1.

In production, the metal parts made in accordance with the invention would be made during briquetting very close to their final desired geometry thereby requiring as little machining as necessary after sintering. Appropriate dies could be made for utilisation in the pressing step.

It should be appreciated that after sintering, the metal part may be subjected to other standard heat treating practices such as carbo nitriding, flame hardening, induction hardening salt bath, and through hardening.

15 WHAT WE CLAIM IS: —

1. A metal part comprising titanium carbide particles of a hardness of 70 or more on the Rockwell C scale and formed by the steps of: preparing a mixture of powdered material having 0.25 to 60 percent by weight ferro titanium and 0.1 to 10 percent by weight carbon, the remainder of said powdered material being substantially iron based powder; compacting said mixture; and heat sintering said mixture above the melting temperature of the ferro titanium powder and below the melting point of the iron based powder whereby the ferro titanium melts and dissolves available carbon in the surrounding matrix to form titanium carbide particles.

2. A metal part as claimed in Claim 1 in which the ferro titanium powder prior to heat sintering has a mesh size (as herein defined) of 40 or less.

3. A metal part as claimed in Claim 1 in which the ferro titanium powder prior to heat sintering has a mesh size (as herein defined) of 325 or less.

4. A metal part as claimed in any one of Claims 1 to 3 in which the mixture contains carbon in the range of 0.5 to 1.5 percent by weight and ferro titanium in the range of 1.0 to 10 percent by weight.

5. A metal part as claimed in any one of Claims 1 to 4 in which the compacted mixture is heat sintered to at least approximately 2,000°F.

6. A metal part as claimed in any one of claims 1 to 5 in which the compacted mixture during sintering is maintained at or above 2,000°F. for a period of approximately one hour.

7. A metal part as claimed in any one of claims 1 to 6 in which the compacted mixture is heat sintered to at least 2,100°F.

8. A metal part as claimed in any one of claims 1 to 7 in which the compacted mixture during sintering is maintained at or above 2,100°F. for a period of approximately 1 hour.

9. A metal part as claimed in any one of claims 1 to 8 in which the compacted mixture is gradually cooled to approximately 825°F. for a period of approximately one

hour; gradually cooled to approximately 825°F. over a period of approximately three hours and then cooled to ambient temperature.

10. A metal part as claimed in any of claims 1 to 9 which is an engine component.

11. A metal part as claimed in claim 1 substantially as herein described with reference to Example 1 or to any one of Samples 1 to 5.

12. A method of forming a metal part comprising the steps of: preparing a mixture of powdered material having 0.25 to 60 percent by weight ferro titanium and 0.1 to 10 percent by weight carbon the remainder of said powdered material being substantially iron based powder; compacting said mixture and heat sintering said mixture above the melting temperature of the ferro titanium powder and below the melting point of the iron based powder whereby the ferro titanium melts and dissolves available carbon in the surrounding matrix to form titanium carbide particles.

13. A method as claimed in Claim 12 in which the ferro titanium powder prior to heat sintering has a mesh size (as herein defined) of 40 or less.

14. A method as claimed in Claim 12 in which the ferro titanium powder prior to heat sintering has a mesh size (as herein defined) of 325 or less.

15. A method as claimed in any of Claims 12 to 14 in which the mixture contains carbon in the range of 0.5 to 1.5 percent by weight and ferro titanium in the range of 1.0 to 10 percent by weight.

16. A method as claimed in any of Claims 12 to 15 in which the compacted mixture is heat sintered to at least approximately 2,000°F.

17. A method as claimed in any of Claims 12 to 16 in which the compacted mixture during sintering is maintained at or above 2,000°F for a period of approximately one hour.

18. A method as claimed in any of Claims 12 to 17 in which the compacted mixture is heat sintered to at least 2,100°F.

19. A method as claimed in any of claims 12 to 18 in which the compacted mixture during sintering is maintained at or above 2,100°F for a period of approximately one hour.

20. A method as claimed in any of claims 12 to 19 in which the compacted mixture is gradually heated to approximately 2,100°F over a period of approximately 2 hours; maintained at approximately 2,100°F for a period of approximately 1 hour; gradually cooled to approximately 825°F over a period of approximately 3 hours and then cooled to ambient temperature.

21. A method of forming a metal part substantially as herein described with refer-

ence to Example 1 or to any one of Samples
1 to 5.

22. A metal part when produced by a
method as claimed in any of claims 12 to
5 21.

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